Plant Physiol. (1970) 45, 231–232

Short Communication

Rotation Axes for Clinostat Studies in Light[1]

Received for publication July 28, 1969

TAKASHI HOSHIZAKI AND K. C. HAMNER
Space Biology Laboratory, Brain Research Institute, and Department of Botanical Sciences, University of California, Los Angeles, California 90024

In clinostat experiments, Lyon (5) found very little difference in the epinastic curvature of branches of *Coleus* and the growth pattern of wheat seedlings whether the plants were rotated around their normal vertical axis or tumbled end over end. Apparently, in darkness, the uniform presentation of gravity around the plant in any one plane is the essential factor. Thus, according to Lyon, no advantage is derived from the use of a second rotational axis in dark experiments. Fischer (2), reporting on single axis clinostat experiments performed in light, stated that illumination from what would normally be "above the plant" did not hinder the leaf movements while illumination from the "side of the plant" stopped the leaf movements. In our previous studies on the effect of simulated weightlessness on plants (3), we have attempted to mitigate and compensate the interaction of light direction and clinostat treatment by using a two-axis clinostat. Because some clinostat experiments must be performed in light, evidence will be presented indicating the need for a second clinostat axis in experiments requiring light.

All plants were treated either on single axis clinostats (4) set to rotate plants around a horizontal axis at 1 rev/4 min or on the double axis clinostat, the Nogravatron (3), set to tumble plants at 1 rev/4 min around a horizontal axis and simultaneously to rotate plants around their normal vertical axis at 1 rpm. Young Pinto bean plants, *Phaseolus vulgaris*, having only two expanded primary leaves were used. In the single axis clinostat experiments, the plants had their stems either coincident or bent perpendicular to the horizontal rotational axis. To prevent extraneous movements and to clarify the leaf blade movements, the stem and the petioles were tied to appropriately bent wire stakes. Eight plants and eight single axis clinostats were placed in a special light box (Fig. 1). The plants were illuminated by fluorescent lamps with light directed parallel or perpendicular to the clinostat axis by means of mirrors. Light intensity ranged from 40 to 60 ftc at leaf level. In the Nogravatron experiments, the stems were left straight and the light intensity at leaf level ranged from 200 to 400 ft-c.

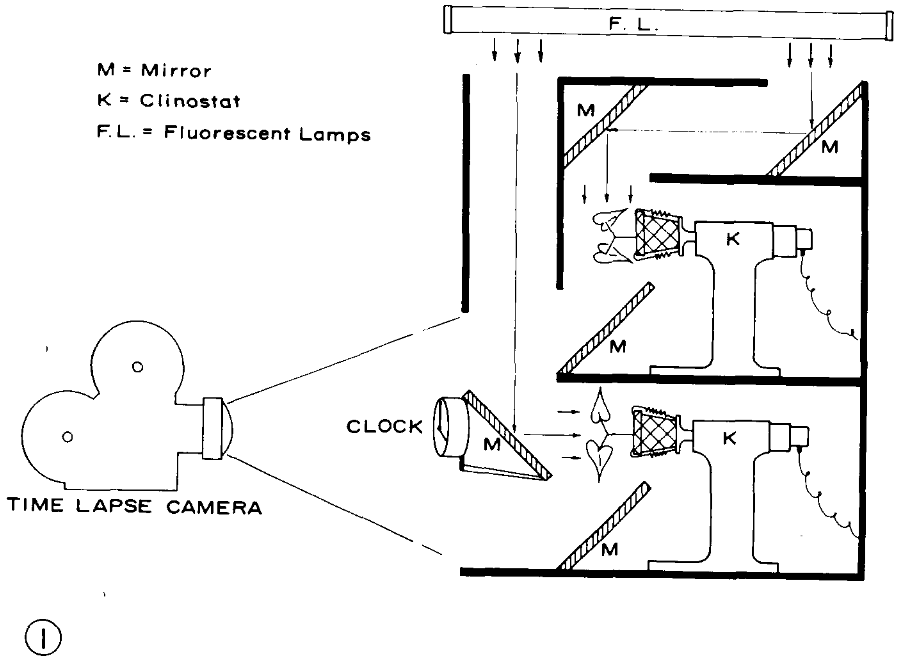

FIG. 1. Arrangement for single axis clinostat experiments. Pinto bean plants, *Phaseolus vulgaris*, were rotated around a horizontal axis once every 4 min. By means of mirrors, light was directed at either the side or top of the plant. The time lapse camera photographed the clock and the images of the plants on the mirrors at the rate of 1 frame every 4 min.

[1] This work was supported in part by National Aeronautics and Space Administration Grant NGR 05-007-174, and by Air Force Office of Scientific Research Office of Aerospace Research, United States Air Force, Contract AF (638) 1387.

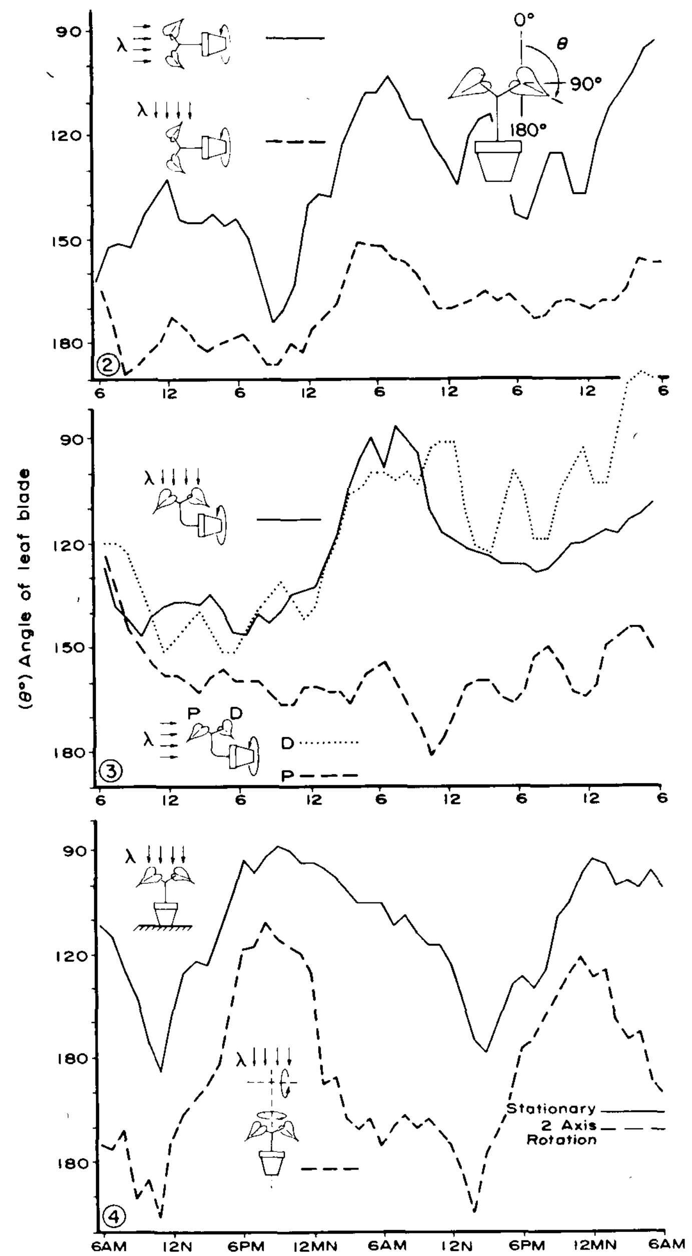

FIG. 2 (top). Single axis experiments. Leaf movements of Pinto beans rotated around a horizontal axis once every 4 min. The stems were parallel with the rotation axis. Direction of light indicated by arrows. Leaf angle values are defined at the upper right. Values are the average of eight leaves.

FIG. 3 (middle). Single axis experiments. Leaf movements of Pinto bean plants with stems bent perpendicular to the rotational axis. Movements of leaves proximal (P) to light source shown by dash lines; movements of leaves distal (D) shown by dotted lines. See Figure 2 for other details.

FIG. 4 (bottom). Double axis experiments. Leaf movements of Pinto bean plants rotated simultaneously around two axes. Leaf movements of stationary controls indicated by solid line. See Figure 2 for other details.

Data were obtained with a 16-mm movie camera set to take a picture every 4 min when the plants were in the same position. The leaf angle measured is the angle between the midrib of the leaf blade and the upper stem regardless of the orientation of the entire plant. The value assigned to the leaf angle is according to Figure 2. Plants were given 12 hr of light and 12 hr of darkness to synchronize the leaf movements and thereafter were given continuous light. Data for the average leaf movements are presented for the first 48 hr of continuous light. Responses after 24 hr of acclimatization in continuous light were analyzed.

On the single axis clinostat, plants having their stems parallel to the rotational axis and with light from the "top" of the plant showed leaf movements from 100 to 140° while plants with light from the "side" of the plant showed leaf movements from 150 to 170° (Fig. 2). Plants having their stems bent perpendicular to the rotational axis and with light given perpendicular to the rotational axis showed leaf movements from 90 to 130° (Fig. 3). With light given parallel to the rotational axis, the leaf proximal to the light source moved from 150 to 180° while the distal leaf moved from 70 to 90° (Fig. 3). These results clearly indicate that the leaves exhibit a phototropic response when rotated on a single axis clinostat.

On the Nogravatron, the leaves moved from 110 to 190° (Fig. 4). The leaf closure was 40° greater than on the stationary plants. This difference probably is due to an epinastic response, since illumination was distributed as efiually as possible from all directions around the plant.

Phototropic responses have been reported (1, 6) for plants centrifuged in light. These responses occurring in a high accelerational field tend to support our findings that plants respond phototropically during clinostat treatments. For clinostat experiments performed in light, a second rotational axis is of value to compensate for unequal distribution of light.

Acknowledgments—We are indebted to Miss Rosemary Dymond and Mr. Richard Kroesing for their technical assistance.

LITERATURE CITED

1. CHANCE, H. L. AND J. M. SMITH. 1946. The effects of light, gravity, and centrifugal force upon the tropic responses of Buckwheat seedlings. Plant Physiol. 21: 452–458.
2. FISCHER, A. 1890. Über den Einfluss der Schwerkraft auf die Schlafbewegungen den Blätter. Bot. Zeitung 48: 673–687, 689–704.
3. HOSHIZAKI, T., W. R. ADEY, AND K. C. HAMNER. 1966. Growth responses of barley seedling to simulated weightlessness induced by two-axis rotation. Planta 69: 218–229.
4. JOHNSON, S. P. 1968. The liminal angle of a plagiogeotropic organ under weightlessness. Experiment P 1017, Final Report, Biosatellite Program, NASA, Washington, D.C.
5. LYON, C. J. 1967. Rotation axes for analysis of gravity effects on plant organs. Plant Physiol. 42: 875–880.
6. WESTING, A. H. 1964. Geotropism: Its orienting force. Science 144: 1342–1344.